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VOLATILE ORGANIC COMPOUNDS IN 600 US HOMES: MAJOR SOURCES OF PERSONAL EXPOSURE

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16. ABSTRACT

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Abstract

The USEPA carried out the Total Exposure Assessment Methodology (TEAM) Study (1980-85) on 600 subjects in five cities representing a total population of more than 700,000 persons. Personal exposures to all prevalent target compounds exceeded outdoor concentrations. Major sources were smoking (benzene, styrene, xylenes, and octane); using hot water (chloroform); wearing dry-cleaned clothes (tetrachloroethylene); and using moth crystals or room air deodorants (para-dichlorobenzene). Eleven of 14 occupations also showed elevated exposures to one or more chemicals (particularly aromatics). Auto related activities (lengthy commuting, filling gas tanks) were associated with increased exposures to several aromatics. Breath concentrations were significantly associated with personal air exposures but not with outdoor concentrations. Residence in major chemical manufacturing and petroleum refining areas did not significantly affect personal exposures.

Study Design

The TEAM Study was designed to measure personal exposures through air and drinking water to 25-30 toxic and carcinogenic volatile organic compounds (VOCs) (1-6). Three petroleum refining and chemical manufacturing areas in New Jersey and California were selected for study, with two comparison areas representing light manufacturing and rural districts in North Carolina and North Dakota. In each area, participants were selected using probability sampling to represent the target population, which ranged from 7000 in North Dakota to 360,000 in Los Angeles, CA. Each subject carried a personal air quality monitor employing Tenax-GC sorbent for two consecutive 12-hour periods, corresponding to the daytime working period and the overnight at-home period. A breath sample was collected at the end of the 24-hour period. Drinking water samples were collected from home and work. In a subset of 120 homes, two consecutive 12-hour outdoor air samples were collected. Questionnaires were administered to each participant to determine personal and household characteristics and activities that could be related to observed exposures.

Results

7853 households were screened to select 591 persons representing 717,000 residents for monitoring in the five areas, some for two or three seasons (880 person-days). 5025 air and breath samples were collected, of which 2010 (40%) were quality assurance (QA) samples. The QA samples included 10% blank Tenax cartridges, 10% control cartridges spiked with all target com-

pounds (including several deuterated compounds); and 20% duplicates, half analyzed at a separate QA laboratory. For most target compounds, blanks had low backgrounds (<10 ng, the equivalent of 0.5 $\mu g/m^3$); however, during some periods, benzene, chloroform, and 1,1,1-trichloroethane had high and variable backgrounds. Recovery efficiencies ranged from 80%-120%. Precision (median relative standard deviations) for duplicate samples was typically 15-25%, with benzene sometimes higher. Side-by-side sampling with the California Air Resources Board, which used a bag sampling method, showed good agreement with Tenax for 11 of 12 chemicals.

Sixteen compounds were prevalent. Mean personal exposures to all prevalent compounds in all areas exceeded outdoor concentrations, often by factors of 2-10. Maximum personal exposures sometimes exceeded outdoor concentrations by factors of 100. Since 85% of subjects did not leave their homes during the overnight monitoring period, their measured exposures may be considered indoor concentrations. The differences between these indoor concentrations and the concurrent outdoor levels are summarized in Tables 1-2.

Table 1. MEAN INDOOR-OUTDOOR DIFFERENCES ($\mu g/m3$) AT TEAM STUDY HOMES

Chemical Class/ Compound	New Jersey Fall (N=84)	New Jersey Summer (N=71)	New Jersey winter (N=10)	Los Angeles Winter (N=24)	Los Angeles Spring (N=24)	Contra Costa Spring (N=10)
Chlorinated (total)	103	54	72	36	29	8
m+p-dichlorobenzene	40	44	14	15	14	0.9
1,1,1-trichloroethane	48	9.2	36	9.2	9.3	2.8
tetrachloroethylene	6.7	5.9	15	7.5	3.0	1.7
chloroform	6.9	-4.4	4.5	1.3	1.8	0.8
trichloroethylene	1.1	-1.3	2.4	2.8	1.1	0.8
carbon tetrachloride	0.6	0.2	0.3	0.0	0.0	0.5
Aromatic (total)	34	25	47	0	18	18
benzene	12	2.6	15	1.6	4.9	4.5
m,p-xylene	8.1	10	16	-1.0	7.6	7.7
o-xylene	3.0	5.2	6.3	0.2	2.3	3.2
ethylbenzene	8.8	6.1	7.5	-0.7	2.2	2.4
styrene	1.9	1.5	1.9	-0.1	0.4	0.3
Aliphatic (total)	NM[a]	NM	NM	9.1	14	7
octane	NM	NM	NM	1.9	2.1	1.0
decane	NM	NM	NM	-0.6	1.5	0.7
undecane	NM	NM	NM	1.1	3.6	2.6
dodecane	NM	NM	NM	1.7	3.1	1.1
α-pinene	NM	NM	NM	5.0	4.0	1.2

aNot Measured

Table 2. MAXIMUM INDOOR-OUTDOOR DIFFERENCES (μg/m3) AT TEAM STUDY HOMES

Chemical Class/ Compound	New Jersey Fall (N=84)	New Jersey Summer (N=71)	New Jersey Winter (N=10)	Los Angeles Winter (N=24)	Los Angeles Spring (N=24)	Contra Costa Spring (N=10)
Chlorinated						
m+p-dichlorobenzene	910	1500	120	190	170	7
1,1,1-trichloroethane	870	110	170	170	87	12
tetrachloroethylene	240	97	67	78	53	3
chloroform	210	34	15	6	18	6
trichloroethylene	32	32	7	49	11	4
carbon tetrachloride	11	4	2	1	0.4	2
Aromatic						
benzene	120	51	42	40	27	21
m,p-xylene	120	150	51	41	85	26
o-xylene	44	94	19	26	27	11
ethylbenzene	310	170	28	22	33	9
styrene	53	9	10	6	2	4
Aliphatic						
octane	NM[a]	NM	NM	36	19	2
decane	NM	NM	NM	8	15	21
undecane	NM	NM	NM	9	72	15
dodecane	NM	NM	NM	9	54	4
α-pinene	NM	NM	NM	39	29	3

[a]Not Measured

Discussion

Cigarette smoking was the major source of exposure to benzene and styrene (7). Smokers averaged 15 μg/m^3 benzene in exhaled breath; nonsmokers averaged 2.5 μg/m3. Nonsmokers who reported workplace exposure to cigarette smoke also showed significant increases of benzene in their breath. Homes with smokers averaged 10 μg/m3 benzene in air; homes without smokers averaged 7 μg/m3. Thus pregnant smokers may be exposing their unborn children to a 6-fold increase in blood benzene concentrations, followed after birth by a 50% increase in airborne benzene levels. Two studies (8,9) have found increased risk of leukemia mortality in children of smoking parents.

About half of all homes showed evidence of elevated levels of para-dichlorobenzene, commonly used in moth crystals, room air deodorizers, and toilet bowl deodorizers. Mean values in all homes ranged from 20-50 μg/m^3 compared to 1-2 μg/m^3 outdoors. This chemical has recently been found to be an animal carcinogen.

Indoor chloroform levels qenerally exceeded outdoor air concentrations by 1-7 μg/m^3. Concentrations in water ranged from 14-70 μg/m^3. Hot water releases chloroform rapidly to the air; thus washing clothes and dishes and taking hot showers and baths are suspected to be the primary sources.

Tetrachloroethylene levels in air and breath were elevated for persons who were employed or who had recently visited a dry cleaning shop. The main source of exposure appears to be wearing and storing dry-cleaned clothes.

Concentrations of 1,1,1-trichloroethane were considerably elevated in homes and in exhaled breath. This chemical is widely used in spray cans as a propellant and in many solvent products.

Trichloroethylene levels were often significantly elevated in women. This chemical is used in some cosmetic and secretarial products.

Carbon tetrachloride concentrations were sometimes elevated in homes although it has been banned from most consumer products. It is used in industrial-strength cleansers and in many fungicides.

Xylenes and ethylbenzene were elevated in the breath of smokers and in the daytime air exposures and breath concentrations of persons employed in certain occupations: chemical manufacturing, paint and plastics plants, and service stations.

Straight-chain hydrocarbons such as decane, undecane, and dodecane were elevated in the air and breath of persons exposed to paint, gasoline, and auto exhaust.

Although α-pinene was elevated in homes, no consistent relationship with any questionnaire variable was found. Presumably it would be associated with wood products in the home.

Auto-related activities such as travel time, visiting a service station, and pumping gasoline were associated with increased exposures to benzene, xylenes, ethylbenzene, octane, decane, undecane, and dodecane.

Categories that consistently were associated with reduced exposures included gardening (possibly because gardeners spend more time outside in the cleaner air) and persons under 18 or over 65 years old (possibly because of reduced occupational exposure).

Multivariate analyses (10) of these data indicate that house-to-house variation within one urban area greatly exceeds the variation between areas. In addition, exposures in heavy petroleum refining areas did not significantly exceed exposures in the "cleaner" urban or even rural areas.

Conclusions

We conclude that personal exposures to nearby sources (room air deodorizers, cigarettes, hot water, dry-cleaned clothes, automobiles) are much more important for most persons than residing in manufacturing areas or near so-called "major point sources" such as chemical plants. Accordingly, individual actions to remove sources from the home are likely to be more effective in reducing exposure than governmental regulations. Also, studies of personal exposure provide the opportunity of detecting important sources that cannot be discovered by ambient monitoring networks. Finally, measuring exhaled breath of nonoccupationally exposed individuals is capable of detecting recent exposures and identifying certain sources of exposure, such as mainstream cigarette smoke, which appears to be the major source of benzene and styrene exposures.

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